PORTLAND CEMENT SIDEWALK CONSTRUCTION

UNIVERSAL PORTLAND CEMENT CO.

CHICAGO — PITTSBURG.

Frontispiece

EXPERIMENTAL WALK LAID BY UNIVERSAL PORTLAND CEMENT CO.

This walk covers about 7,000 square feet and was laid at the Company's No. 3 Plant, Buffington, Ind., October, 1907, for the purpose of obtaining some definite data on the causes of failure in sidewalk construction.

Portland Cement Sidewalk Construction

BY

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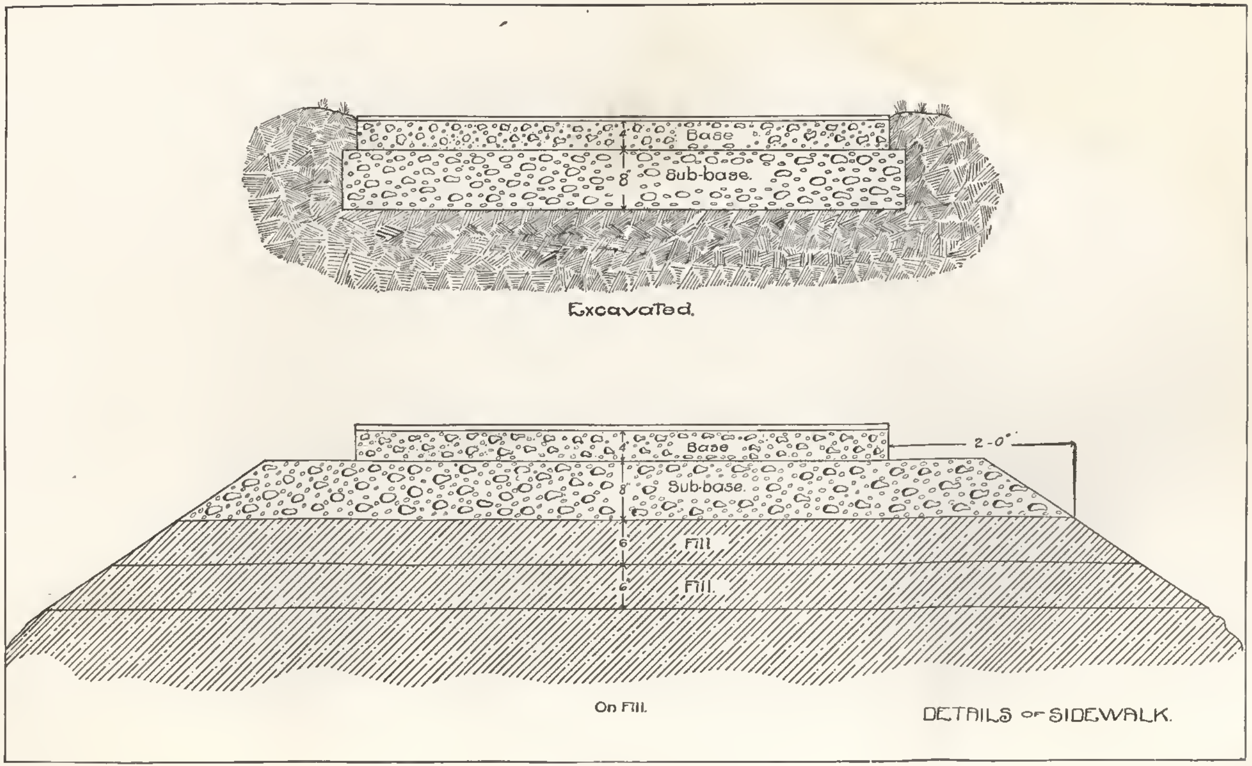
Foreword

The apparent ease with which concrete sidewalks may be constructed has led many of the uninitiated to undertake such construction with little experience and less knowledge of the requirements necessary to obtain the best results. Properly constructed, such walk has no superior as regards appearance, cleanliness and lasting qualities.

To set forth the requirements necessary to obtain the best results in Portland cement sidewalk construction, is the object of this booklet.

The specifications presented are preceded by general notes and comments which, it is hoped, will impress upon the reader the importance of enforcing the rules of the specifications.



Base
4"
Sub-base.
8"
Excavated.
Base
4"
Sub-base.
8"
Fill.
6"
Fill.
6"
2'-0"
On Fill.
DETAILS OF SIDEWALK.

FIGURE 1.

PORTLAND CEMENT SIDEWALK CONSTRUCTION

THE object of a sidewalk is to provide an even and solid surface for pedestrians. To whatever extent a material or construction fails to provide evenness and solidity, to the same extent the material or construction is unsuitable or defective. Permanency is another quality in a sidewalk which should be provided, unless prohibited by first cost.

Board walks hardly need mentioning, for the cost of lumber and its short life in a sidewalk prohibit such construction, excepting in very limited localities.

Brick has been used so long and so extensively as a sidewalk material, one might naturally suppose that it quite fully meets the essential points referred to. A very superficial study, however, shows that this material is not at all adapted to the purpose of sidewalk construction, though through force of habit, brick are still used to a small extent in some of the older and less progressive communities. In the light of present day requirements, brick are wholly unsuited for sidewalk construction, because walks of brick are usually very uneven and lack permanency.

Large flags sawed from durable stone make an excellent walk, but many times stone incapable of standing sidewalk wear is used, and also the cost of such walk is excessive, excepting at points in the immediate neighborhood of the origin of the stone.

Portland cement concrete sidewalk, when properly constructed, meets all the requirements of evenness, solidity and permanency, and in practically all localities, can be built at a cost, when its superior points are taken into account, which makes it competitive with all other material. The possibilities of this splendid material are well appreciated, but often, through lack of knowledge of the material and inexperience in handling it, many walks are built which, sooner or later, become more or less defective. The cause of these defects will be pointed out and a means by which they may be avoided suggested.

In dealing with this subject stress will be laid upon points that may be considered by some as of minor importance, but a study of the subject has shown that defective work frequently results from failure on the part of the builder or the engineer, to appreciate the importance of watching closely the smaller details.

There are certain rules which should be observed in all cases, and in some cases additional precautions are necessary. The location of a walk is determined regardless of the natural fitness of the foundation, the soil and drainage conditions and it is important, therefore, that these matters be carefully studied. The materials available should also receive careful attention, and should be selected with reference to quality and not altogether with reference to cost. The weather condition at the time a walk is constructed has a marked effect upon its behavior, and must be taken into account to assure permanence.

Poor workmanship, which includes improper proportioning of materials, the placing of a walk on an improperly prepared foundation and failure to take into account weather conditions, is responsible for practically all failures that occur. Failures which can be positively charged to poor materials are few, though frequently materials are used which could be improved by a more careful and intelligent selection, without adding to the cost of the finished work. The quality of the work should always receive first consideration and first class materials should always be used, even though the cost is somewhat increased by the use of such materials. The principal expense in this class of construction is the labor item, and the labor will be the same whether good or poor materials are used.

It is not uncommon to hear, as an argument to prove proper workmanship in a defective walk, that the same workmen had laid satisfactory walk by the same methods. Granting that the same workmen may have built two walks in the same manner does not prove that the necessary precautions are always observed. The conditions might vary materially, and unless all points receive due consideration, success could result in one case, while failure would follow in another. The necessary qualifications, therefore, for the construction of sound and lasting work are good materials, proper methods and careful workmanship. Failure to provide these will often result in disappointment.

MATERIALS

The selection of materials is the first consideration, and, as in all construction, an important matter.

Cement. The methods here given assume the use of Portland cement of high grade. Natural and Puzzolan cements are unsuited for the form of construction under consideration,

the former because of its low strength and inability to resist abrasion, and the latter because in work above ground it is weakened by the action of the atmosphere.

In small jobs, it is only necessary to secure cement from a reputable manufacturer, but where the quantity of work will justify, it is advisable to have the cement tested. The methods for testing, adopted by the American Society of Civil Engineers, January 20, 1904, and amended January 15, 1908, should be used and the cement should comply with the Standard Specifications for Cement of the American Society for Testing Materials, adopted June, 1904, together with subsequent changes and amendments.

Aggregate. The quality of the work is just as dependent upon the sand, gravel and crushed stone as upon the cement, and the question of aggregate should receive the same careful attention. In fact, it should receive more attention, for much more dependence can be placed on a reputable brand of cement than on a natural deposit of sand, gravel or stone.

While Portland cement is carefully manufactured under the supervision of trained chemists and engineers, the aggregate is usually taken from a natural deposit, and may or may not be a suitable material; also wide variations in the character of the material in different parts of the same deposit are not unusual.

In selecting an aggregate, the character of the surfaces presented by the particles should always receive close attention; these must be hard and permanent. A covering of any fine material will interfere with the cement or mortar getting into contact with the surface of the aggregate and the strength will be reduced proportionately. An excellent precaution in this respect is to avoid the use of dirty materials.

Some experimenters found that certain sands gave better strength with the addition of 10 or 15 per cent of finely divided clay than when tested without the clay. This, however, is no argument in favor of dirty materials. The addition of a small percentage of finely divided clay might be permissible when the clay is treated as a separate material, while even a much smaller quantity naturally occurring in the aggregate might make it wholly unfit for concrete purposes.

In order to obtain the best results, the aggregates should be well graded; that is, must not contain an excess of one size particles and contain but a small percentage of fine particles. In the case of stone, the material will usually be quite satisfactory,

provided the stone in itself is hard and durable and not affected by exposure to the elements, and provided it is prepared and marketed under conditions which assure its being clean and free from a covering of dust or other matter.

Some stone, though apparently quite hard, presents a chalky surface with which it is impossible for the cement to form a perfect bond. Stone of this character should be avoided, for it cannot possibly produce good concrete.

In sand and gravel, one is dealing with entirely different materials, but materials probably to be preferred to stone and screenings when selected with sufficient care. The use of sand and gravel is very popular, due to the ease with which they are obtained in many localities. Where these materials are readily secured, they are frequently used as they come from the deposit with little or no thought given to their fitness for the work at hand. The character of the materials which are sometimes used in concrete is surprising. Aggregates should always be firm and hard and should remain so when exposed indefinitely to the weather. It is quite common to find a considerable quantity of shaly pebbles in some of the glacial sands and gravels of the upper Mississippi Valley. These pebbles are not strong in the first place and disintegrate readily when exposed to the elements. They also absorb water readily when used in concrete and expand under the combined action of moisture and frost, injuring the concrete to a more or less extent. Though the effect of the soft sand grains is not so apparent as is the effect of the larger pebbles, such sand cannot possibly produce first-class results if the shaly particles form any considerable portion of the sand content. In the territory referred to it is not unusual to find sidewalks badly pitted and marred, as a result of the disintegration of this shaly material. These shaly particles are undesirable, because they are both weak and unstable. A concrete can never be stronger than the material making up the aggregate.

The size of the sand grains and the relative proportion of grains of different size have a very marked effect on the value of the sand. See Table B.

At least 75 per cent. of a sand should be retained on a 40 mesh sieve with the particles well distributed between that size and the size passing a 4 mesh sieve with an increasing proportion on the coarser sieves. Such a sand will have much less total surface than one composed of equal proportions of

particles on the several sieves. A sand made up entirely of fine particles will present a very much larger surface which must be covered with cement, than either of the sands above mentioned. For instance, the total superficial surface of a given volume of spheres one-sixty-fourth inch in diameter is sixteen times the surface of the same volume of spheres one-fourth inch in diameter. As the making of a first-class concrete necessitates the perfect covering of every particle of sand with cement and every particle of the coarser aggregate with the cement-sand mortar, it is apparent that materials with an excess of fine particles should be avoided. The same line of reasoning is applicable to the combined aggregate in the concrete.

Occasionally one sees a mixture of cement and sand used for the concrete base in sidewalk construction and cannot help being impressed with the fact that the user fails to appreciate the requisite of a good concrete.

In Table A will be found a physical analysis of a material taken from a sidewalk job in which it was being used for the concrete in the proportion of one part cement to four parts aggregate.

TABLE A—SAND ANALYSIS

Weight of Sample—500 Grams										Measured and Computed Voids		Specific Gravity
*Percentage Retained on Sieve No.									Thru No 200	Measured	Computed	
4	10	20	30	40	50	80	100	200				
2.0	15.4	14.6	17.5	11.0	5.3	27.2	2.1	3.7	1.0%	29.2	33.2	2.614

The general quality of this material was fairly good, though it will be noted that only 2 per cent. of it could be considered gravel. No particles found in the sample were larger than ½ inch. The voids in the sand were 33 per cent., by displacement 29 per cent. The mixture of 1 cement to 4 sand, therefore, was out of balance, the cement not being sufficient to fill the voids. Not only did this volume of sand contain more voids than the cement could fill, but the excess of fine material detracted from the value of the sand as it was being used, because it presented a very much larger surface than the cement could possibly cover. By referring to Table D, it will be seen that with a sand having

*The sieve number refers to number of meshes per linear inch.

Sample 1.

Sample 2.

FIGURE 2.

The sands represented by Samples 1 and 2 were screened from a gravel of glacial origin at Attica, Indiana. This material is excavated by steam shovel, screened into several sizes and washed. Samples 1 and 2 illustrate very clearly the possible variation in sands taken from the same deposit, and also in a general way give a fairly correct idea of the appearance of a well graded sand. From Table B can be obtained the granulometric analysis of these samples, together with their relative strength under compression when mixed in a 1:3 mortar.

NOTE.—Figures 2, 3 and 4 show the materials actual size.

29 per cent. of voids, only 2½ parts should be mixed with 1 part of cement, and assuming that a coarser aggregate containing 45 per cent of voids was available, 4½ parts of such aggregate could be mixed with the 1 cement–2½ sand mortar, and the concrete thus produced would be far superior to the mixture of 1 part cement and 4 parts sand which was being used, at the same time effecting a saving of about 50 per cent of the cement.

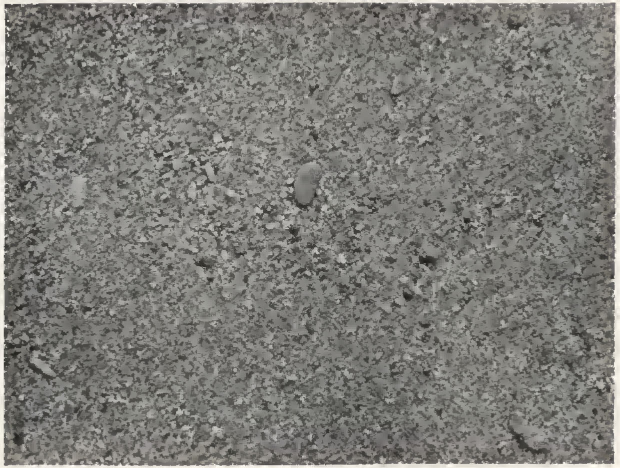
Table B and Figures 2, 3 and 4 reproduced from Bulletin No. 331, Series R, Structural Materials, 3, United States Geological Survey, show distinctly the comparative value of sands of like composition and general character, but varying in relative proportions of different sized grains.

TABLE B—COMPARATIVE VALUE OF SANDS

Sample Number.	Source of Supply.	Location.	Percentage of Voids.	Percentage of Silt.	*Percentage Retained on Sieve No.						Compressive Strength at One Year. 1:3 Mortar in Pounds Per Square Inch.
					10	20	30	40	50	Thru 50	
1	Bank Sand . .	Attica, Ind. .	34.0	3.9	4.1	16.3	16.0	19.0	13.8	30.0	4475
2	" " . .	" " . . .	26.9	0.7	27.1	26.9	16.4	14.3	7.2	7.3	7750
3	River Sand . .	St. Clair River	40.5	2.0	1.0	1.8	2.0	8.5	25.3	60.0	2729
4	" " . .	" " "	29.7	0.2	39.5	27.5	11.6	9.4	6.8	4.7	6742
5	Limestone . .	St. Louis, Mo.	42.1	10.1	9.9	40.3	13.7	7.9	7.2	31.0	4908
6	" . .	Greenfield, O.	37.5	1.1	44.4	21.4	8.5	4.9	3.4	17.4	8500

Comparing Samples 1 and 2, Table B, taken from the same sand bank near Attica, Indiana, and differing only in size of grains, it will be noticed that when made up into a 1:3 mortar, the compressive strength of Sample 2 is more than 70 per cent. greater than the compressive strength of Sample 1. As other conditions are the same, it is evident that the low strength shown by Sample 1 is due entirely to poor gradation and excess of fine particles. Like conditions prevail with Samples 3 and 4 taken from the St. Clair River near Detroit, Michigan. Sample 3 is a very fine sand, 60 per cent. passing the 50 mesh sieve and the effect of such fine material is readily discernible in the compressive strength. Sample 4, which represents a well graded sand from the same stream, gives a compressive strength nearly 150 per cent. greater than Sample 3.

*The sieve number refers to number of meshes per linear inch.



Sample 3.

Sample 4.

FIGURE 3.

The sands represented by Samples 3 and 4 were taken from the St. Clair River by a centrifugal pump. As these samples were taken from the same stream, their composition and general character, excepting size of particles, must naturally be quite identical. By reference to Table B, as well as the illustrations above, it will be seen that the two sands are very different in granulometric composition. It will also be noted that the compressive strength of the two sands when made up into a 1:3 mortar, is very much in favor of the coarser sand.

That a large proportion of fine particles in limestone screenings is detrimental is shown by the tests on Samples 5 and 6. Here also the compressive strength is in favor of the coarser material, Sample 6 being more than 70 per cent. stronger than Sample 5.

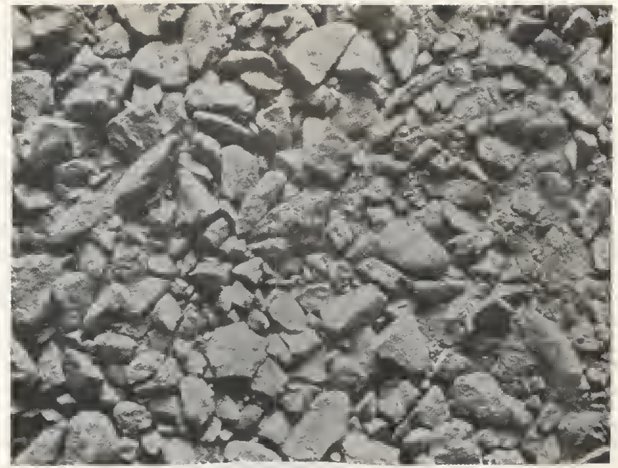
Although the same precautions regarding fine material are not necessary in the case of gravel and crushed stone, the arguments in favor of well graded material are equally applicable. To give the maximum strength and require at the same time the least cement, the aggregates should be so graded that each successive size material will fill the interstices left by the preceding larger size. Of course, such ideal material is not a commercial article, but in selecting an aggregate the points which go to make up the ideal should be kept in mind.

The relative percentage of voids in two materials, one of uniform size and shape, and the other of irregular size and shape, is clearly shown by comparing the sand in Sample 2, Table B, with the voids in a mass of round shot of uniform size. In the former case, the voids equal 26.9 per cent., while in the latter they equal 47.6 per cent. That is to say, there will be nearly twice the space in the sand to fill with cement if the grains are round and all the same size.

Size of Aggregate. A study of Table C, which compares the principal requirements in the specifications for cement sidewalks of thirty-six cities, indicates that aggregates exceeding $1\frac{1}{4}$ inches in diameter should not be used. Undoubtedly there are many gravels which would give good results, though containing larger sizes, but this limit is safe and the one most often applied to this class of work. The lower limit, $\frac{1}{4}$ inch, which is also the upper limit for sand and stone screenings, is almost universally accepted.

Unscreened Gravel. In many districts, unscreened gravel (gravel as it comes from the bank containing both coarse and fine particles), is used. This practice should be avoided, as such material usually contains a large excess of sand, and would be much improved if screened and the proper proportions of fine and coarse particles remixed. The increased value of the remixed aggregate over the natural material would more than justify the additional expense. The case referred to in Table A, illustrates this point quite clearly.

Sample 5.



Sample 6.

FIGURE 4.

The limestone screenings represented by Sample 5 were taken from a crushing plant near St. Louis. Of the crusher run material received at the laboratory, 50 per cent. passed through ¼-inch screen The grading of the screenings is not at all uniform, as shown by the granulometric analysis.

Sample 6 was taken from a crushing plant at Greenfield, Ohio, and represents the screenings separated from the crusher run material by ¼-inch screen. It will be noted that with the exception of the large amount of fine material, the screenings are very well graded and the strength developed by this material, when mixed in the proportion of 1:3, is very much superior to that developed by Sample 5, when mixed in the same proportion. See Table B.

FOUNDATIONS

The foundation must provide a permanent bed for the walk and serve as a means for disposing of water which would otherwise accumulate under the walk. In many localities, a well constructed sub-base will offer sufficient drainage, but in some soils and under some conditions, additional drainage is necessary.

Drainage. If water is allowed to accumulate in the sub-base, there is danger of the walk being heaved by frost. Therefore, in soil where the sub-base and the natural drainage cannot take care of the water, other drainage should be provided. The best means of supplying this additional drainage will depend somewhat upon the available outlets, etc. See Figures 5 and 6. In some cases stone filled trenches properly placed at intervals along the walk will provide adequate drainage, while in other cases a tile drain will be necessary.

Paragraphs from Specifications for Sidewalk Construction, both of Pittsburg and Cincinnati, are quoted, which describe the type of special drains used in these cities.

Department of Public Works, Pittsburg, Pennsylvania. Paragraph 404.

Foundations. "The foundations shall be of cinder or broken stone, as hereinbefore specified, and shall be drained to the curb ditch by 10"x12" stone drains placed every twenty-five (25) feet along the line of the walk." See Figure 5.

Board of Public Service, Cincinnati, Ohio. Paragraph 3.

"By 'sub-drainage' is meant a line of three-inch diameter round, butt-joined, hard-burned drain tile laid as directed by the engineer. The outlet or discharge for the drain to be by connection with the street inlets, or in the absence of street inlets by such other arrangements as the engineer may prescribe."

Material. The material to be used for the foundation or sub-base of a walk will depend to a great extent upon the locality in which the work is contemplated. The builder can best determine from the materials available, which one is the most satisfactory and economical. The one chosen must be of such a character as to withstand tamping without crushing to the extent that it will prevent proper drainage. Steam cinders are commonly used for the sub-base, and if the fine material is eliminated, they afford a solid foundation and provide excellent drainage.

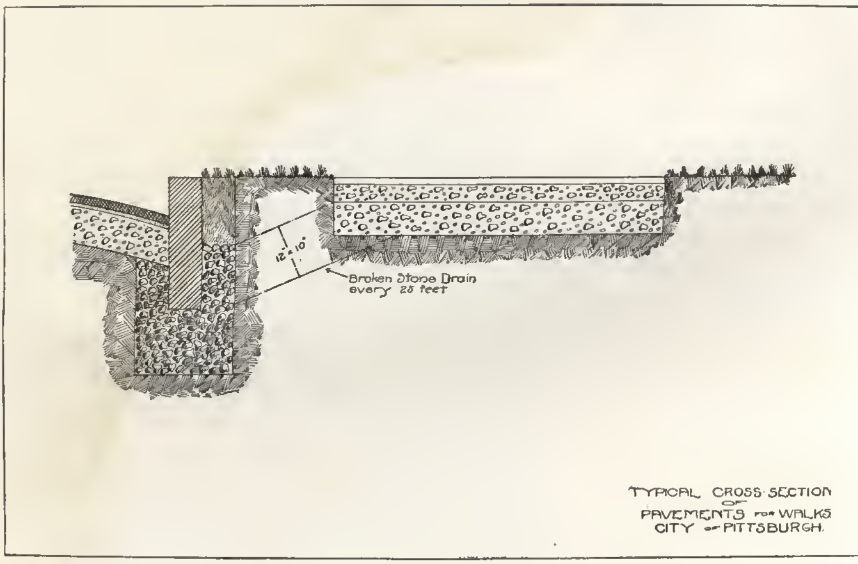


FIGURE 5.

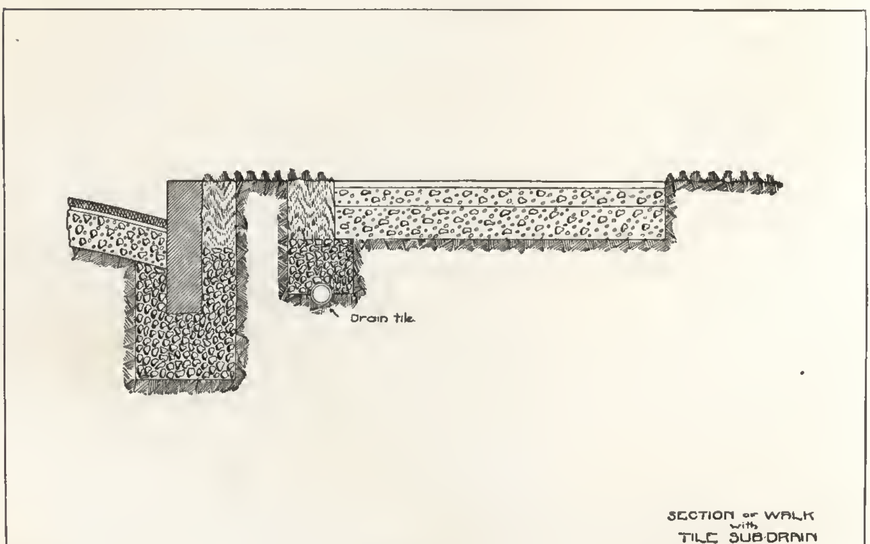


FIGURE 6.

Construction. In the construction of a walk, it is necessary that the foundation be so built that neither time nor the elements can change its ability to support the walk. Improperly constructed fills and poor sub-bases result in a great many defective walks. Typical examples of such defects are shown in Figures 7, 8 and 9. It is true that a crack through the center of a walk may not necessitate its rebuilding, but when it is understood that perfect walk can be obtained with so little additional effort, such failures are absurd. If the foundation settles to any great extent, the walk will be practically destroyed, unless it is built strong enough to resist breaking and to tilt instead.

FIGURE 7.
Crack through center of a 6 foot walk, resulting from poor foundation.

Preparation of Sub-Grade. As walks seldom rest upon the top of the ground, it is usually necessary to prepare the sub-grade upon which the sub-base or foundation is established. This is done by either of the two methods shown in Figure 1. If the soil at the excavated grade is firm and solid, there is no necessity for further preparation, but if it contains any soft or spongy places, these should be removed and the holes filled with firm material and packed solidly. When the sub-grade occurs on fills its preparation requires more care and it is not strange that many foundation failures can be traced to improperly made fills. In Figure 1, two imaginary 6-inch layers are shown at the top of the fill to emphasize the fact that at least the upper portion

FIGURE 8.

FIGURE 9.

Figures 8 and 9 show plainly the necessity of providing a proper fill and then preserving it. In this case the fill was of sand, and was scarcely wider than the walk. Not being properly protected, it was rapidly destroyed. At one point the walk was undermined nearly a third of its width. Although the walk was of fairly good construction, it is being broken away, as is shown in Figure 9.

of the fill should be tamped in layers not to exceed 6 inches in thickness, and in no case should one undertake to compact a fill in layers exceeding 10 inches in thickness. When the material and conditions will permit, the intelligent use of water will assist greatly in compacting a fill. The reason for extending the fill and sub-base beyond the walk at the line of the sub-grade, as shown in Figure 1, is made evident by Figures 8 and 9. Here the breaking off of the edge of the walk was due to the fact that the fill was made too narrow and then left unprotected. The sides of the fill and sub-base should be given a slope of about 1:1½, so that it will not slip away, and when granular materials are used, the slope should be banked with sod or clay.

The sub-base should be flooded and tamped on the sub-grade to the proper level. This should be done on approximately the lines shown in Figure 1, though the sub-grade may be an imaginary line, as is the case when fills are made of the same material used in the sub-base.

PROPORTIONING

It is surprising how little interest is manifest in actual practice in determining the best and most economical proportions for concrete to be made from a given material. Any piece of work is large enough and of sufficient importance to justify a study of the aggregates for the purpose of determining the correct proportions. Mr. W. B. Fuller states that the ordinary mixture for water-tight concrete is about 1 part cement, 2½ parts sand and 4½ parts of coarser aggregate, which requires 1.37 barrels cement per cubic yard of concrete. By carefully grading the materials he did on one occasion obtain water-tight concrete with a mixture of 1 part cement, 3 parts sand and 7 parts coarse aggregate, which reduced the cost of the concrete 58 cents per cubic yard. When it is appreciated that the terms strength and density, or water-tightness, are quite synonymous when applied to concrete, it is readily seen that Mr. Fuller obtained a concrete in the 1:3:7 mixture equally as strong as the 1:2½:4½ mixture at a very marked reduction in cost.

Under ordinary conditions, the most practical way of arriving at the proper proportions is by the determination of voids. By voids in a mass of material is meant the space that is occupied by air. These air spaces, or voids, are usually referred to as a percentage of the whole volume.

TABLE C

City	Minimum Thickness: Sub-Base	Minimum Thickness: Base	Minimum Thickness: Top	Max. Rise per Foot	Drain	Proportions: Base 1 Cement to
Augusta, Ga.	4″	3″	1″	⅓″	Not Specified	2 Sd. : 4 S. or B.
Baltimore, Md.	4″	4″	1″	½″	" "	3 Sd. : 6 S.
Boston, Mass.	12″	3″	1″	⅜″	" "	2 Sd. : 5 S.
Buffalo, N. Y.	3″	3″	1¼″	½″	" "	6 Gr.
Cedar Rapids, Ia.	5″	4″	*	¼″	3″ Tile in 1′ × 1′ Trench.	3 Sd. and Gr.
Chattanooga, Tenn.	2″	3″-4″	1″	⅓″	Not Specified	3 Sd. : 6 S. or Gr.
Chicago, Ill.	9″	4¼″	¾″	⅓″	" "	2½ Sd. : 5 S. or Gr.
Cincinnati, O.	8″	3″	1″	⅜″	3″ Tile where Eng. directs.	2 Sd. : 5 P. or Bp. or Bld.
Cleveland, O.	6″	3″	1½″	N. S.	Not Specified	6 Gr. or 3 Sd. : 6 Sl. or S.
Columbus, O.	8″	3″	1″	⅜″	3″ Tile where Eng. directs.	2 Sd. : 4 Cs, or Gr.
Grand Rapids, Mich.	N. S.	3½″	½″	¼″	Not Specified	4 Sd. : 8 Gr.
Kansas City, Mo.	6″	3½″	½″	¼″	" "	2 Sd. : 4 Cs. 1 Sd. : 4 J. F. or Gr.
Lincoln, Neb.	3″	3″	1″	N. S.	" "	4 Gr. + Sd. to fill, or 3 Sd. : 4 S.
Little Rock, Ark.	N. S.	3¼″	¾″	"	" "	2 Sd. or Scr. : 4 Cs. or Gr.
Los Angeles, Cal.	6″ 2″†	3″	½″	"	" "	3 Sd. or Scr. : 5 Gr. or S.
Minneapolis, Minn.	1″	2½″	¾″	"	" "	4 Sd.
New Orleans, La.	N. S.	4″	1″	"	" "	3 Sd. + S. so mortar overfills 20%.
N. Y.—Brooklyn	7″	4″	1″	"	" "	3 Sd. : 6 S.
N. Y.—Manhattan	7″	4″	1″	"	" "	2 Sd. : 4 S.
Philadelphia, Pa.	14″	3″	1½″	"	" "	3 Sd. or Gr. : 6 S.
Pittsburg, Pa.	6″	3″	1″	¼″	12″ × 10″ S. 25′ c to c	3 Sd. : 6 Cs. or Gr.
Portland, Ore.	N. S.	3″	¾″	N. S.	Not Specified	3 Sd. : 5 or 6 Cs. or Gr.
Rochester, N. Y.	6″	N. S.	1″	⅜″	" "	2 Sd. : 4 Cs. or Gr.
San Francisco, Cal.	N. S.	3″	½″	N. S.	" "	4½ Gr. or Cs. + Sd. to fill voids.
Seattle, Wash.	"	3½″	½″	"	Drain Tile where Eng. dr.	3 Sd. : 6 Gr. or Cs.
South Bend, Ind.	"	3¼″	¾″	¼″	Not Specified	2 Sd. or Scr. + S. so mortar overfills 2 parts
Springfield, Ill.	4″	4″	1″	¼″	" "	3 Sd. + S. so mortar overfills voids.
Springfield, O.	8″	3″	1″	N. S.	" "	5 Gr.
Superior, Wis.	8″	3″	1″	"	See Specific.	3 Sd. : 5 S.
Stewart, J. A. Cincinnati‡	8″	3″	1″	"	3″ Tile in 4″ × 6″ trench.	2 Sd. : 4 Gr.
St. Louis, Mo.	8″	3½″	½″	"	Not Specified	3 CG.
St. Paul, Minn.	4″ S. 6″ Cds.	3″	1″	"	" "	3 Sd. : 5 S.
Syracuse, N. Y.	N. S.	3″	¾″	"	" "	3 Sd. : 6 S. or Gr.
Toledo, O.	6″ Gr. 8″ Cds.	3″	1″	⅜″	" "	3 Sd. : 5 S. or Gr.
U. S. A. Ft. Sheridan	10″	4″	1″	N. S.	" "	2 Sd. : 4 S.
Youngstown, O.	4″	3″	1″	¼″	" "	6 Sd. : Gr. or S. so mortar overfills voids.

* Mortar for top flushed from rich base by tamping. † 2″ on "adobe" soil.
‡ Engr. for number of villages near Cin't'i.

ABBREVIATIONS.

Broken Bowlders	= Bld.	Gravel	= Gr.	Stone	= S.
" Brick	= B.	Granite	= G.	Soft Coal Cinders	= SCds.
" Pebbles	= Bp.	Granite Screenings	= GScr.	Screenings	= Scr.
Cinders	= Cds.	Hard Coal Cinders	= HCds.	Sand	= Sd.
Crushed Granite	= CG.	Joplin Flint	= J. F.	Slag	= Sl.
" Stone	= Cs.	Not Specified	= N. S.	Torpedo Sand	= Torp.
Dust	= Dst.	Pebbles	= P.		

TABLE C

CITY	Proportions Top 1 Cement to	Foundation Kind	Size of Aggregate Base	Size of Aggregate Top	Methods of Mixing§ Base	Methods of Mixing§ Top	Size of Blocks
Augusta, Ga......	1 Sd.	N. S.	Thru 1¼″	N. S.	No. 1	No. 1	4′ Square
Baltimore, Md....	1 Sd. or 1 Sd. : 1 Scr.	Cs. or Substitute	Thru 1½″	Thru ¼″	N. S.	N. S.	5′ Long
Boston, Mass.....	1 Scr. or 1 Sd.	Cs. Gr. SCds.	¼″-2¼″	" "	No. 1 2	"	12 sq. ft. to 36 " "
Buffalo, N. Y.....	2 Gr.	Cds. or S.	N. S.	" "	No. 2	No. 1	4′ Wide
Cedar Rapids, Ia..	N. S.	Cds. Gr. Cs. Sd.	Thru 1″	N. S.	No. 2	*	3′ : 6′ Long
Chattanooga, Ten.	1½ Sd. or CG.	Cds. Sl or Gr.	" "	¼″ less 30% Dst.	No. 1	N. S.	25 sq. ft.
Chicago, Ill.	1½ Sd. or Scr.	Cds.	¼″-1″ Spl.	Thru ⅛″	No. 1 3	"	5′×6′ Abt.
Cincinnati, O......	1½ Sd.	SCds.	¼″-1″	No. 4 Screen	No. 1	No. 1	4′: 6′ Long
Cleveland, O......	2 Sd.	Cs. Sl. Cds. or Gr.	1½″	Special	No. 1 3	No. 1	5′×6′
Columbus, O.	1½ GScr or 1 Sd. : ½ Torp.	SCds. or Sl.	½″-1½″	No. 4 & Spl.	No. 1	No. 2	4′:6′ Long
Gr'd Rapids, Mich.	2 Sd.	N. S.	¼″-2½″	Thru ¼″	No. 2	No. 1	6′ Wide
Kansas City, Mo. .	1½ Sd.	Cds.	No. 16-¾″	" No. 8	No. 2	N. S.	6′ Long
Lincoln, Neb.	1½ Sd. : 2Scr,	Cs. or Cds. or B.	S.1½″ Gr. ⅛″-1″	" ½″	N. S.	"	N. S.
Little Rock, Ark. .	1½Sc. or Scr.	N. S.	N. S.	N. S.	"	"	6′ one way 25 sq. ft.
Los Angeles, Cal. .	1½ Sd.	Gr.	Gr.¼″-3″ or Cs.¼″-2″	Scr. thru ¼″	No. 2 3 2	No. 1 3 2	N. S.
Minneapolis, Minn.	2 Sd.	Sd.	Sd.	N. S.	No. 2	No. 1	"
New Orleans, La. .	1 Sd.	N. S.	Thru 2″	Special	No. 3	N. S.	"
N. Y.—Brooklyn .	1½ Scr.	Cds.	¼″-1¼″	Thru ¼″	No. 1	No. 1	4 : 6 ft. sq.
N. Y.—Manhattan	" "	"	" "	" "	N. S.	No. 1	4 : 6 ft. sq.
Philadelphia, Pa. .	1 Scr.	HCds.	¼″-2″	" ⅜″	No. 1 4	N. S.	6′ Square
Pittsburg, Pa.....	2 Scr.	Cs. or Cds. 1″-3″	¼″-1½″	S. thru ¼″	No 1 3	No. 1	N. S.
Portland, Ore.....	1 Sd.	N. S.	½″-2	N. S.	No. 1	N. S.	3′ Square
Rochester, N. Y...	1½ Sd. or Scr.	Gr. Cs. SCds. Thru 2″	Thru ¾″	Thru ¼″	No. 1 6	"	4′ Long
San Francisco, Cal.	1Gr.	N. S.	¼″-1¼″	N. S.	No. 1 3	No. 1	3′ Square
Seattle, Wash.....	1 Sd.	"	¼″-1½″	"	No. 1 3	No. 1	2′ "
South Bend, Ind. .	1 Sd.	"	Thru 1″	"	No. 1	No. 1	N. S.
Springfield, Ill....	1 Scr.	Cds.	Millrun	"	No. 1	N. S.	"
Springfield, O.....	1⅜ Sd.	Gr.	N. S.	"	No. 2	No. 1	5′×6′
Superior, Wis.....	1 Sd. or Scr.	Gr. Cds. Cs.	S1″Gr.1½″	"	N. S.	No. 1	Special
Stewart J. A. Cincinnati ...	2 Sd.	Cds.	½″-1″	Thru No. 4	No. 1	No. 1	N. S.
St. Louis, Mo.....	1 Scr.	Cds. Thru 2″	Thru ¾″	N. S.	No. 2	N. S.	"
St. Paul, Minn....	1½ Sd.	Cs. or B. SCds.	½″-1½″	"	No. 1	No. 1	4′ : 6′
Syracuse, N. Y....	1½ Sd.	Gr. Cds. Cs.	¼″-1″	Thru ¼″	No. 1	No. 1	5′×5′
Toledo, O.........	2 Sd. or Scr.	Gr. Scr. Cds.	Thru 1″	N. S.	No. 1	No. 1	N. S.
U.S.A. Ft. Sheridan	1½ Sd.	5″ Cds. or Scr. and 5″ Cs. thru 2″	" ¾″	Special	N. S.	N. S.	6′ Long
Youngstown, O. ..	2 Sd.	Mill ash or Sl.	" 1″	N. S.	"	No. 1	4′ : 5′ Long

§METHODS OF MIXING

BASE

No. 1—Cement and Sand dry, then wet. Incorporate stone (wetted) with mortar.
No. 2—All materials dry, then wet.
No. 3—Cement and Sand dry. Wet stone added and mixed.

TOP

No. 1— { Cement and Sand or screenings dry. / Cement and Sand or screenings wet.
No. 2— { Cement and Sand or screenings dry. / Cement and Sand or screenings thru No. 4 sieve. / Cement and Sand or screenings wet.

Number in lower *left* hand corner means number of turns *dry*.
Number in lower *right* hand corner means number of turns *wet*.

Determination of Voids. Before undertaking to determine the voids in a coarse aggregate, see if it is dry and porous. If so, it should bc wetted and then dried just enough to remove all moisture from the surface of the material. In this way the error which would occur from absorption of water is eliminated.

In determining voids, a cylindrical metal vessel of at least 1 cubic foot capacity should be used. To determine the voids in a coarse aggregate the vessel is weighed and then filled level full with water and weighed again. Call the net weight of the water C. Remove the water; dry and fill the vessel level full with the aggregate; weigh and call the net weight of the aggregate B. Pour water slowly into the aggregate until the vessel is again level full of water; weigh and call the net weight of the aggregate and water A.

The formula then is:—

$$\text{Per cent. Voids} = \frac{A-B}{C} 100$$

Example:

C=Weight of Water=62.5 pounds.
B= " " Aggregate=100 pounds.
A= " " " and Water=131 pounds.

$$A-B=131-100=31.$$

$$\begin{array}{l} 62.5\,)31.0000\,(\ .496\times 100=49.6\%. \\ \quad\ \ \underline{2500} \\ \quad\ \ \ \ 6000 \\ \quad\ \ \ \ \underline{5625} \\ \quad\ \ \ \ \ \ 3750 \\ \quad\ \ \ \ \ \ \underline{3750} \end{array}$$

In introducing the water into the vessel containing the aggregate, care must be taken to prevent entrapping air. It is good practice, therefore, to apply the water all at one point along the side of the vessel.

In determining voids in sand and stone screenings, the scheme outlined for coarser aggregate may be applied with a slight modification. Instead of pouring the water into the sand-filled vessel, the sand should be poured into a vessel containing water. The vessel should be filled not less than half full of water and the sand introduced slowly. The object in pouring the sand into the water is to eliminate the air, which is impossible if the order is reversed.

As most sands have less than 50 per cent. voids the water will overflow the vessel before it is level full of sand. When this point is reached, care should be taken to keep the loss of fine particles down to a minimum. When the vessel is level full of sand and water, and all the overflow of water carefully wiped off, the weight is determined and the formula given for the coarser aggregate applied.

Grading Aggregate. In many cases it would be economical to avoid the use of stone or gravel having excessive voids by introducing material of a size that would reduce the voids. For instance, if the aggregate is found to be approximately one size, and much smaller than the maximum allowed, the voids will be reduced by introducing coarser material; if on the other hand, the material is of a size approximately the maximum allowed, the voids will be reduced by the addition of finer material ranging in size from the coarse aggregate to the coarsest sand. It will cost some more to handle an additional material, but in many cases it will prove economical.

When unscreened gravel is used, the percentage of sand should be determined and if the ratio of the particles which pass through $\frac{1}{4}$ inch screen is to the particles retained on the screen as 3: 5, then a mixture of 1 part cement and 8 parts of the unscreened gravel may be used. Addition of stone or sand may be made to such gravel to bring it to the desired proportions, but it is usually advisable to separate the fine and coarse material and obtain the proper mixture in a definite manner.

Cement, Weight Per Cubic Foot. While not disagreeing with those authorities who place the weight of a cubic foot of cement at 100 pounds, it is recommended, for such work as is being considered at least, that a sack of cement weighing 94 pounds be accepted as a cubic foot in proportioning concrete. This will make it a simple matter to mix the materials in the proper proportions, if each batch is made some multiple of one sack of cement. This practice will save time and avoid confusion.

The permissible error which will occur in determining voids by the method suggested and the possible error in accepting 94 pounds as a cubic foot have been compensated in Table D by adding 10 to the percentage of voids found in the small aggregate and calculating the mixture from this sum.

Measuring Materials. The practice of shoveling the sand and stone directly upon the mixing platform without measuring is bad

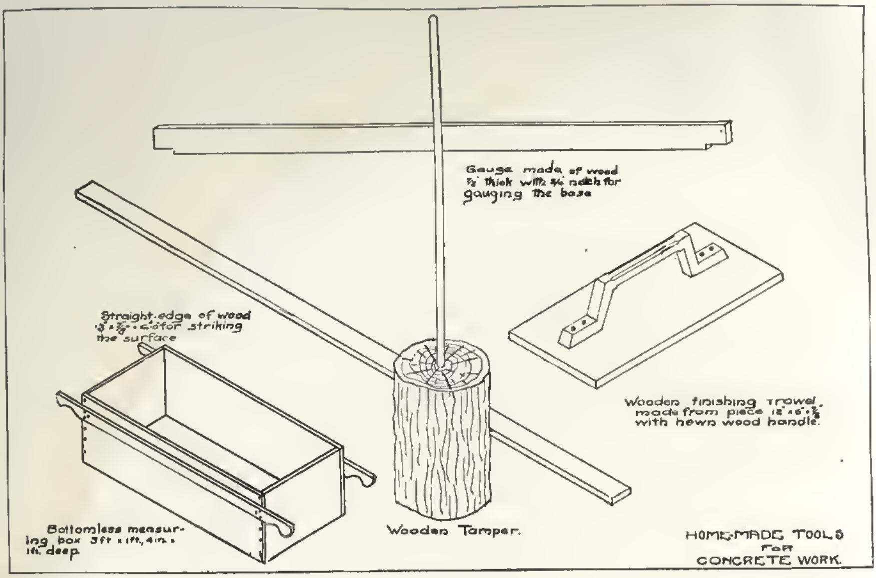


FIGURE 10.

and should never be permitted. It is always best to measure the materials in an accurate manner, but to measure them in wheelbarrows, the capacity of which have been carefully determined, is permissible, provided the loads placed in the wheelbarrows are carefully gauged.

A measuring box of 3 or 4 cubic feet capacity should be part of the equipment of every sidewalk crew. Though the materials may be measured in wheelbarrows, or in some other manner which is quite reliable, the measuring box will be found convenient for checking up measurements and for measuring batches which require less than full wheelbarrow loads. Such a box can be graduated so that one, two or more cubic feet can be accurately measured. A convenient form of measuring box is shown in Figurc 10, and is rectangular, without a bottom, and provided with a short handle at each corner. In using the box, it should be placed upon the mixing platform, filled and struck off. The box is then lifted, leaving the material on the platform.

FORMS

In general wood will be used for the forms, though thin strips of metal will be found convenient in forming curved lines. Also the use of the metal cross-form or parting strip, shown in Figure 11, will be a guarantee against defects arising from imperfect

TABLE D

Showing Proportions of Cement, Sand and Stone for Different Percentages of Voids in Sand and Stone

Voids in Sand, Per Cent.	Parts of		Voids in Stone, Per Cent.														
	Cement	Sand	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
			Parts of Stone.														
19	1	3.5	7.5	7.5	7.0	7.0	7.0	7.0	6.5	6.5	6.5	6.5	6.0	6.0	6.0	6.0	6.0
20	1	3.5	7.0	7.0	7.0	7.0	6.5	6.5	6.5	6.5	6.0	6.0	6.0	6.0	5.5	5.5	5.5
22	1	3.0	7.0	6.5	6.5	6.5	6.5	6.0	6.0	6.0	6.0	5.5	5.5	5.5	5.5	5.5	5.0
24	1	3.0	6.5	6.0	6.0	6.0	6.0	6.0	5.5	5.5	5.5	5.5	5.5	5.0	5.0	5.0	5.0
26	1	3.0	6.0	6.0	6.0	5.5	5.5	5.5	5.5	5.0	5.0	5.0	5.0	5.0	5.0	4.5	4.5
27	1	2.5	6.0	6.0	5.5	5.5	5.5	5.5	5.0	5.0	5.0	5.0	5.0	4.5	4.5	4.5	4.5
28	1	2.5	5.5	5.5	5.5	5.5	5.5	5.0	5.0	5.0	5.0	5.0	4.5	4.5	4.5	4.5	4.5
29	1	2.5	5.5	5.5	5.5	5.0	5.0	5.0	5.0	5.0	4.5	4.5	4.5	4.5	4.5	4.5	4.5
30	1	2.5	5.5	5.5	5.0	5.0	5.0	5.0	5.0	4.5	4.5	4.5	4.5	4.5	4.5	4.0	4.0
31	1	2.5	5.5	5.0	5.0	5.0	5.0	5.0	4.5	4.5	4.5	4.5	4.5	4.5	4.0	4.0	4.0
32	1	2.5	5.0	5.0	5.0	5.0	5.0	4.5	4.5	4.5	4.5	4.5	4.5	4.0	4.0	4.0	4.0
33	1	2.5	5.0	5.0	5.0	4.5	4.5	4.5	4.5	4.5	4.5	4.0	4.0	4.0	4.0	4.0	4.0
34	1	2.5	5.0	5.0	4.5	4.5	4.5	4.5	4.5	4.5	4.0	4.0	4.0	4.0	4.0	4.0	4.0
35	1	2.0	5.0	4.5	4.5	4.5	4.5	4.5	4.5	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.5
36	1	2.0	4.5	4.5	4.5	4.5	4.5	4.5	4.0	4.0	4.0	4.0	4.0	4.0	3.5	3.5	3.5
37	1	2.0	4.5	4.5	4.5	4.5	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.5	3.5	3.5	3.5
38	1	2.0	4.5	4.5	4.5	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.5	3.5	3.5	3.5	3.5
39	1	2.0	4.5	4.5	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.5	3.5	3.5	3.5	3.5	3.5
40	1	2.0	4.5	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.5	3.5	3.5	3.5	3.5	3.5	3.5
41	1	2.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
42	1	2.0	4.0	4.0	4.0	4.0	4.0	4.0	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.0	3.0

joints or expansion. The cross-form should be made of ⅛-inch metal with stiffeners of the same thickness on the ends and top. Wedges are to be driven from the outside into the ½-inch clearance space between the wooden side forms and the metal cross-form.*

The wooden forms should be constructed of clean lumber free from warp, and at least 2 inches thick by about 5 inches wide. Surfaced lumber has advantages, but its use is not necessary.

In placing the side forms along the line of the walk, care should be taken to maintain a good alignment and they should be leveled so as to conform with the finished grade.

Providing for Surface Drainage of Walk. The form nearest the street should be slightly below the inside form, thus providing a drain which will prevent water from collecting on the walk. The side forms should be securely staked,

*After going to press it was learned that a patented metal cross-form similar to the one described has recently appeared in the market.

the stakes alternating on either side about every two feet. If the special metal cross-form is used, fewer stakes will answer, for when the form is keyed into position, it is rigidly fastened and holds the outside forms in their proper relative position.

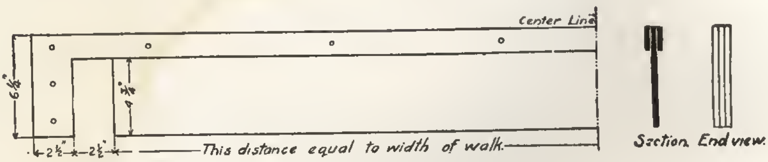


FIGURE 11.

Wooden cross-forms need only be held in place by stakes on the opposite side from which the concrete is to be deposited. When the concrete is being placed, a shovelful or two will hold the cross-forms firmly until it is tamped into position.

When wooden cross-forms are used, the location of the joints should be definitely determined and plainly marked on the side forms before any concrete is placed. The cross-forms should be placed so that the face against which the concrete is to be packed is in line with the points indicating the position of the joints.

Providing for Expansion Joints. About every 50 feet one of the wooden cross-forms should be replaced by a metal parting strip, which should be left in the walk until it is opened to traffic, when it will be removed and the opening thus produced filled with paver's pitch or other suitable material. This forms an expansion joint, which insures the walk against such defects as are noticeable in Figures 12 and 13. This precaution is also necessary when a new walk abuts curbing or other cement or stone walk.

MIXING

Obtaining the proper proportions does not guarantee first class concrete. Proper mixing counts for much. The sand and cement should be first mixed dry and then mixed wet into a homogeneous mortar. The coarse aggregate, previously drenched, should be added to this mortar, and all thoroughly mixed together. This practice can be followed in either hand or machine mixing, provided a batch mixer is used. On small work, hand-mixing seems to be the most popular, and if honestly done, will be entirely satisfactory. But oftentimes mixing is sorely neglected, being intrusted without proper supervision to laborers who have

little appreciation of what is really necessary and less interest in final results. Machine mixing, when the batch type of mixer is used, is much more certain and reliable.

Consistency. Generally speaking, wet concrete will give better results than dry, and though it is not practicable to use as wet concrete in sidewalk construction as in some other classes of work, the concrete should be mixed with as much water as it will stand and permit of thorough tamping. Probably all who have had anything to do with mixing concrete by hand have noticed that the mass becomes more moist as the mixing progresses. This is because the particles are being forced into closer contact, and indicates that the object of the mixing is being accomplished. The same plasticity is apparently obtained by the use of an excess of water and less mixing. This does not give the same results and should never be substituted for thorough mixing. The mixing should always be conducted in a manner which will not permit of the loss of cement through the running off of surplus water.

Hand-Mixing. Hand-mixing is accomplished most satisfactorily by spreading the sand upon a level, water-tight platform, or other non-absorbing surface, to approximately a uniform depth; the cement should be spread evenly over the sand and the two mixed until the mass assumes a uniform color. Water should then be added and the mass of sand and cement converted into a smooth mortar by more thorough mixing. Upon this mortar, spread the required amount of crushed stone or gravel, which has been previously drenched, and mix thoroughly until all particles are well coated with the mortar. When the mixture so obtained is too dry, additional water should be added and the whole mass given at least another turn.

When a natural mixture of sand and gravel is used, the material should be handled the same as sand, that is, it should be spread evenly and after the addition of cement, mixed thoroughly dry and then wet.

Hand-mixing is treated in detail, not because it is thought to be superior to machine mixing, but as different results are obtained with different types of mechanical mixers, the results desired are more definitely indicated by reference to the hand method than otherwise. Any mechanical mixer which will produce the same results will, of course, be permissible, but care should be taken that the mixing is always thoroughly done.

FIGURE 12.

FIGURE 13.

The effects produced by expansion in walks are clearly shown in Figures 12 and 13. In Figure 12, two slabs of the walk have been destroyed by expansion, while in Figure 13 the curb against which the walk was constructed has been broken away. It can be clearly seen in Figure 13 that the walk is now projecting something more than an inch inside the curb line. The construction of the walk in Figure 12 was first-class but for the omission of expansion joints. This break in the walk occurred about midway of a stretch approximately 200 feet long, abutting other and older walk at both ends. These figures illustrate the importance of providing expansion joints both in the walk and where the walk abuts a curb or non-yielding bodies.

Care in Adding Water. Care should always be exercised in adding water to a concrete mixture, for if the water is introduced in a flood, as it is sometimes, by carelessly dashing from a bucket, the cement is washed from the mixture. The water should never be added faster than it can be taken up by the materials, excepting that when water is first introduced, it can be applied in a quantity if the material is formed into a basin or trench which will prevent the water from flowing from the mass. When additional water is required in a mixture, it is an excellent practice to add it in a spray, such as is obtained by the use of an ordinary sprinkling can with a perforated nozzle.

Quantity to be Mixed at One Time. The size of a batch of concrete should be governed by the speed with which it can be mixed and deposited, but should never exceed 1 cubic yard.

Retempering. Under no circumstances should concrete or mortar, which shows perceptible hardening or drying out, be remixed and used. Any disturbance of concrete after hardening has begun will weaken it. Usually concrete which is retempered is a portion of a batch and, therefore, the real value is small. The saving which may result from the use of such concrete will not justify the introduction of uncertainties into the work. Any practice which has a tendency to weaken the work should be avoided. Such defects as are shown in Figures 14 and 15 may result from the use of retempered concrete.

PLACING

With the sub-grade and sub-base properly prepared and with good materials correctly proportioned and thoroughly mixed, the assembling of these in a manner which will result in a permanent structure should not be neglected. The concrete should be deposited within the forms on a sub-base previously wet and tamped into final position as quickly as possible. On hot, drying days, the concrete should not be permitted to stand after the mixing is completed, but should be placed immediately, even though it necessitates mixing smaller batches.

Any appreciable drying of the concrete, either before or after placing, is apt to result in defective work.

Preserving Proportions. Proper regard should be shown for the preservation of the proportions by preventing loss of material in any way. The greatest danger of loss is probably by over-loading the wheelbarrows. The cement being fine, is to

FIGURE 14.

The lines shown in the walks represented by Figures 14 and 15, are incipient cracks made prominent by the deposit of dirt from water which has filtered through them. This is a common and unsightly defect, and at first glance might be attributed to shrinkage, but careful examination of such markings fails to reveal any contraction; in fact, the presence of cracks is sometimes difficult to detect if the dirt is removed. By an examination of work showing these defects, it will be found invariably that the top is hard, strong and probably of sufficient thickness, while the base is imperfectly bonded and often porous and weak. This permits a slight readjustment of the particles in the base resulting in an uneven and indeterminable settlement. As concrete has practically no elasticity, the under side of the top layer is thereby subjected to a tensile stress greater than it can bear. A crack starts and extends through to the surface. The size of these cracks is greatly exaggerated by the dirt accumulated. Sometimes a single crack of this kind occurs in a slab but at other times the surface is badly checked, as shown in the illustrations. In Figure 15, the slab illustrated was the only one defective in about thirty which were laid at the same time, and this was in the middle of the work. The failure of this slab was probably due to concrete being permitted to stand too long either before or after placing, which would explain why this slab behaved differently from abutting slabs. While the top will at times be found loose, giving a hollow sound when struck, the same effect occurs as frequently where the bond is perfect between the top and the materials in the base in immediate contact with it, but where the base is weak. These cracks do not form in new work, but in concrete which has been laid several months and thoroughly hardened. In time frost opens the cracks and destroys the walk. By the use of good concrete properly placed, such defects will be avoided.

a more or less extent carried in suspension in the surplus water in the mixture and by loss of any water, the concrete is robbed of a portion of its most vital constituent.

It cannot be emphasized too strongly that water is one of

FIGURE 15.

the necessary materials for the production of concrete. The materials must be mixed in the first place with sufficient water and then the loss of moisture by evaporation or otherwise must be prevented.

Tamping. Concrete of the consistency referred to on page 31, will permit of tamping and should receive it. The forms should be filled to the top with concrcte and then tamped until the top of the base is at least $\frac{3}{4}$ of an inch below the top of the forms. This will permit of a $\frac{3}{4}$-inch top and care should be taken that at least this thickness of top is provided for throughout the walk. The only way this minimum top can be assured is by the use of a straight edge made to gauge the top of the base $\frac{3}{4}$ of an inch below the top of the form. See Figure 10. The tamping should bc continued until the gauge will clear the concrete at all points. Such a straight edge or gauge is a simple affair and is easily made.

Driveways. Wherever a walk is crossed by a driveway, the thickness of the base should be increased at least 2 inches and the top should have a minimum thickness of $1\frac{1}{4}$ inches.

Preserving Joints in the Base. If a wooden cross-form is used, it will be removed, together with the stakes that sup-

port it, after the concrete is thoroughly compacted, and the perpendicular wall of the new concrete slab should be carefully preserved, the next slab being tamped directly against it.

Another practice, which was common a number of years ago, is to lay alternating slabs entirely independent of each other. After the first set is completed, the alternating positions are filled. By this practice each slab becomes an independent flag and if constructed properly, can be treated as such if occasion demands. A slight unequal movement in the foundation supporting such slabs might result in the walk becoming somewhat uneven, see Figure 16, but the slabs would seldom break and could be raised and the sub-base regraded, thus saving the walk. Many a walk otherwise good has been destroyed because it was constructed as a monolith over a large area and the foundation supporting it was not absolutely stable.

The use of the metal cross-forms, shown in Figure 11, is another means of forming a perfect joint between abutting slabs. The form is left in position until the adjoining slab is placed complete with top. In fact, it is well to leave it in until the slabs are receiving their final treatment, when it can be raised and the groover run over the space from which it has been removed. The projection beyond the outside forms makes it convenient to raise the metal from its position between the slabs.

Parting Strip Provides for Expansion. Besides providing a perfect joint between abutting slabs, this metal form provides a $\frac{1}{8}$-inch expansion joint, which overcomes the necessity of leaving a larger and more noticeable joint at intervals along the walk.

The practice of placing as a monolith a long stretch of walk and depending upon being able to cut through the top and base, is *bad*, and should never be permitted. Results of this type of construction are to be seen on every hand.

Avoid Fractional Slabs. Carelessness of one kind encourages another and when walks are being laid where it is possible to run in long stretches, one frequently sees a fractional part of a slab left over at quitting time, and when work is resumed, new concrete is placed against the portion which was previously placed and a top spread over the whole. As the bond between the two concrete bodies is weak at best, a crack will invariably occur at the juncture. A fractional part of a slab should never be left over upon suspending work even for the noon hour. The concrete should be packed against the cross forms so that when placing of

concrete is resumed, it will start from a vertical joint between abutting slabs. Any concrete left over at the time work is suspended should be discarded if the work is stopped long enough to permit of any hardening or perceptible drying out of the mass.

FIGURE 16.

In Figure 16 is shown quite a large area covered by concrete slabs. It will be noted that though these slabs are somewhat uneven, due to the unequal settlement of the foundation, they are not cracked or broken as would have been the case had the slabs not been constructed independently of each other. This clearly illustrates the advantage of providing perfect joints between all abutting slabs. Though this walk is uneven, it is serviceable, and can at comparatively small expense be put in first-class shape, whereas had the slabs been constructed without perfect joints, the settlement which has occurred would have destroyed the walk.

FINISH AND FINISHING

The top finish for a walk should be constructed with the idea of securing maximum wear, a smooth but not slippery surface, and a uniform shade or color, but one which will not reflect light too strongly. The question of durability is governed by the aggregate used and by the proportions of cement and aggregate;

the smoothness, by the size and shape of the aggregate, the kind of finish and amount of troweling; the color, by the materials composing the top and the character of the finish. A smooth troweled finish reflects light more than any other. If the walk is of a uniform color, the fact that the color may not agree exactly with an adjoining walk should not be given serious thought.

Top Floated. The top or finished surface of a walk may be placed in two or three different ways. The most common is to mix the top mortar very thin and to float it on; that is, to spread it slightly and then work it down with a straight edge until the surface is worked to quite a true plane, flush with the top of the form.

Top Tamped. Another method is to apply to a base, which has been tamped into position, a stiff mortar and tamp it into place and finish the same as the floated top is finished. The tamping this material receives flushes water to the surface, and makes it possible to finish in the usual way. When the top mixture is to be tamped into place, it must be heaped up somewhat above the top of the form. After being thoroughly tamped and moisture has accumulated on the top, the mass should be struck with a straight edge and the low places brought to grade. A top coat put on in this manner can be finished with much less delay than can the floated top. If the mixture is of the proper consistency and the top properly applied, it also assures a more perfect bond between the top and the base.

Top Mortar Flushed from Base. To make the base rich in mortar and raise a top mortar over this by tamping is still another method, but one which has not, so far, gained much favor. In placing a walk of this construction the form is filled as outlined, excepting the base mixture is well heaped above the forms and then tamped to grade.

The usual tamping may be followed by a special tool which will assist in forcing the coarse stone from the surface and in bringing mortar to the top. This tool is illustrated in Figure 17, and can be made by any blacksmith.

Consistency of Top Mortar. When the top is applied independent of the base, it should be a mixture of about 1 part Portland cement with $1\frac{1}{2}$ parts good, clean, coarse sand, or screenings. See Table C. If the top is to be tamped down with the base, the consistency should be such as to permit of thorough tamping. A top to be floated must be mixed with considerable more water, but care should be taken to avoid getting

it too thin, as a very much longer time is required before it can be finished, and it is apt to show sandy spots when completed.

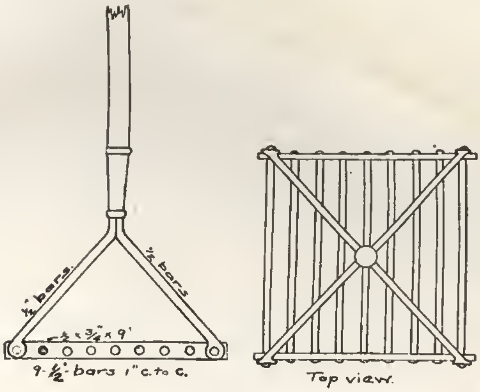


FIGURE 17.

To Avoid Loose Tops. The placing of the top finish should receive the closest attention. Loose tops are altogether too common, and sooner or later the base becomes uncovered. See Figure 18. In all cases, the top should be applied as quickly as possible after the base is tamped into position. If the base becomes dry, as it will in a very short time during warm weather, there is no assurance that the top will bond with the base, unless special precautions are exercised in placing it. Often the base is permitted to become dusty and dirty, both by dust being blown from the street and from careless workmen walking over the fresh concrete. Also sand is often carelessly dropped on the base. In all such cases, the concrete should be freed of the foreign matter, and over the affected parts should be spread a thin wash of neat cement and water.

Placing Top on Hardened Base. In cases where the application of the top has been unavoidably delayed and the concrete has hardened and is dry, or where it is desirable to place a new top on an old base, some special treatment will be necessary to perfect a bond between the top and the base. One method which is quite successful is to drench the concrete and thoroughly cleanse the surface, removing all loose and foreign matter, and then to apply a thin grout or wash of neat cement and water. If the surface being treated will permit of it, the grout should be brushed into the concrete by vigorous scrubbing with a stiff fiber brush. When the surface is properly prepared, the top is applied in the usual way.

Surface Treatment. The surface treatment which a walk receives depends largely upon the practice in the community in which the work is being done. The smooth, steel trowel finish is probably the most common and at the same time the poorest finish used. Such a finish frequently results in crazing or hair-checking of the surface, which is due to nothing more than a slight contraction which takes place in a film formed on the surface by the steel trowel. Besides the smooth finish showing every little blemish and variation in color, it is much more slippery than any of the other finishes.

The wooden trowel finish is growing in popularity, and certainly has many points in its favor. The brush finish is similar to the wooden trowel finish, but it requires an additional tool, and one that can be used for no other purpose. The finishes that are produced by special tools, like the tooth roller, etc., have little to commend them. They are in no way superior to the rough finish produced in a more simple manner, and do not harmonize so well with the usual surroundings.

FIGURE 18.

The section of the walk shown in Figure 18, clearly illustrates careless construction. Though the base in this walk was fairly solid, it was not as strong as it should have been, and was covered with a thin, weak top, which failed to bond to the base.

Color. The number of points which affect, more or less, the color or shade of a walk is quite remarkable. It is only with

the greatest care that a workman will be able to produce continuously walk of a uniform shade. Of course different materials will give different effects, but though the builder is so fortunate as always to obtain the same grade of materials, he will still find that his results are equally dependent upon other things.

Conditions Governing Shade or Color. The shade of a finished walk will vary with the consistency of the mixture, the amount of troweling, the character of the finishing tool used, the time which elapses between placing and finishing the top and with weather conditions and temperature; also with the treatment and protection the work receives during the first 48 hours after it is completed. Of course weather and temperature conditions are beyond the builder's control, but he should make allowance for these and conduct his work accordingly. It is not unusual to see walk, which has been laid either in the late fall or spring, of two different shades, according to whether it was in the sunshine or shadow. Work affected in this manner usually bleaches out all right in time, but until this occurs, the appearance of the walk is not pleasing. The lack of uniformity of shade or color in the same walk is much more noticeable than the lack of uniformity of shade or color in abutting walks. Therefore, in all construction an effort should be made to produce uniformity in color throughout a walk.

It has probably been noticed by every sidewalk builder that a steel trowel gives a darker finish than a wooden trowel or float, and that a dry mixture gives a darker finish than a wet one. Also, that if the top is allowed to become too dry after being floated, and then finished with a steel trowel, it is apt to contain blotches which remain indefinitely. A walk allowed to harden under a sand covering tends to bleach out lighter in color than one which is exposed to the air during the hardening period. Probably all who are interested in sidewalk construction have noticed that the opposite sides of a stretch of walk will frequently appear to be of different shades, as the result of half of it being finished from one side, while the other half was finished from the opposite side. This indicates clearly how very sensitive a sidewalk finish is to treatment.

Colored Surfaces. Colored surfaces are not easily obtained and for ordinary sidewalk work are seldom required. If a colored surface is desired, the coloring matter should be mixed with the whole of the top coat. It is advisable to experiment

with the cement and aggregates one proposes using, and if possible, obtain the color desired before undertaking to apply a colored surface to a walk, or similar construction, for with only the greatest care will it be possible to obtain uniform coloring throughout and definite proportions must be determined and strictly adhered to.

The following paragraph and table are taken from "Cement and Concrete," by Louis C. Sabin, M. Am. Soc. C. E., and contain suggestions which probably will be of value where colored work is contemplated.

> "The addition of coloring matter to cement and concrete is not at present widely practiced, and consequently experience has not been sufficient to indicate just what colors may be used without detriment to the work. Lampblack has been most commonly employed, giving different shades of gray according to the amount used. In any large work where the use of coloring matter is desirable and there is not time to institute thorough tests, the advice of a cement chemist should be sought. The dry mineral colors, mixed in proportions of 2 to 10 per cent. of the cement, give shades approaching the color used. Bright colors are difficult to obtain and would not be in keeping with a masonry structure except in architecture.
>
> "When mixed with an American Portland cement mortar, containing 1 part cement to 2 parts by weight of a yellow river sand, the particles of which are largely quartz, the colors indicated in the following table are obtained.
>
> "With no coloring matter added, the mortar was a light greenish slate when dry. Ultra marine green, in amounts up to 8 per cent. of the cement, had no apparent effect on the color of this mortar. Variations in character of cement and sand will affect the result obtained in using coloring matter. The colors indicated below are for dry mortars; when the mortar is wet the shades are usually darker. None of the materials mentioned in the table seems to affect the early hardening of the mortar, though very much larger proportions might prove injurious. With red lead, however, even 1 per cent. is detrimental, and larger proportions are quite inadmissible."

COLORED MORTARS

Colors Given to Portland Cement Mortars Containing Two Parts River Sand to One Cement

Dry Material Used	Weight of Dry Coloring Matter to 100 Lbs. Cement.				Cost of Coloring Matter per Pound (cents).
	½ Pound	1 Pound	2 Pounds	4 Pounds	
Lamp Black..	Light Slate .	Light Gray ..	Blue Gray.. .	Dark Blue Slate......	15
Prussian Blue	Light Green Slate.....	Light Blue Slate......	Blue Slate ...	Bright Blue Slate......	50
Ultra Marine Blue......	....	Light Blue Slate......	Blue Slate. ..	Bright Blue Slate......	20
Yellow Ochre.	Light Green .	....	....	Light Buff. ..	3
Burnt Umber.	Light Pinkish Slate..	Pinkish Slate	Dull Lavender Pink......	Chocolate....	10
Venetian Red	Slate, Pink Tinge.....	Bright Pinkish Slate. ..	Light Dull Pink......	Dull Pink....	2½
Chattanooga Iron Ore. ..	Light Pinkish Slate..	Dull Pink ...	Light Terra Cotta	Light Brick Red	2
Red Iron Ore.	Pinkish Slate	Dull Pink ...	Terra Cotta. .	Light Brick Red	2½

Marking. There might possibly be some chance for argument regarding surface finish, but certainly surface marking will not permit of any. The position of the joints between the slabs should be determined before the base is placed and provided for in the construction. Positive joints should always be provided in the base of the walk. These are the real joints and the markings in the top should always occur over them. It is not sufficient to make a surface marking, together with a feeble effort toward cutting through the base with a small trowel or similar instrument. More walks are disfigured by failure on the part of the builder to provide proper joints than by any other cause. Figures 19, 20 and 21 are splendid examples of such unsightly defects.

Size of Slab. The size and shape of the slabs into which a walk is divided is governed very largely by the width of the walk, the local practice and personal tastes. Other points, however, should be considered; in fact, local practice and personal tastes should be eliminated entirely when walks on business streets are being constructed. Where the whole space between the building line and the curb is to be covered, many angles and irregular lines are introduced owing to openings, steps, etc. Steps should never be constructed over a joint, nor should a joint ever

FIGURE 19.

FIGURE 20.

The cracks which have occurred in the walks shown in Figures 19 and 20 were caused by the builder failing to provide perfect joints through the center of the walk. These walks were built on fills of 2 or 3 feet, and naturally there was some unequal settlement. If the slabs making up the walks had been built independent of each other, or had perfect joints been provided between the slabs, the cracks would have been prevented by the opening of the joints.

In Figure 19, the crack discontinued after crossing five slabs. This probably was because the foundation under the sixth slab from the starting point remained permanent and the joint between the fifth and sixth slabs opened, permitting the fifth slab to settle without disturbing the adjoining one.

In Figure 20, it will be noted that the crack starts at a point where the joint refused to yield, crossed two slabs and returned to the joint where it again opened.

be permitted to intersect a step (excepting at a joint), unless the walk and step are constructed entirely independent of each other. Joints between the slabs should be placed so as to avoid small corners and unnecessary angles; in fact, so far as possible, all slabs should be rectangular. Also the joints in new work, abutting old, should always be projected from the joints in the original work, unless a distinct open joint is provided between the new and the old. The necessity of observing these precautions is made manifest by Figures 22 and 23.

FIGURE 21.

The importance of exercising care in placing a joint or surface marking in a walk immediately over the joint in the base is shown in Figure 21. In this case the surface marking was a little to one side of the joint in the base and about parallel with it. A slight motion in the foundation caused a crack to occur immediately over the joint in the base, but it would have followed the surface marking if it had been properly placed.

CARE AND PROTECTION

When a walk is completed, care should be taken to protect it from the elements.

Effect of Rain and Frost. Rain falling on green work will make it rough and unsightly, while too rapid drying and frost are apt to result in hair checking and will also have a tendency to weaken the concrete in a general way.

Protecting Against Rain and Sun. As most walks are constructed during the summer months, protection against rain and sun is of first importance. Unless the practice of pro-

tecting all new walk is followed, the tendency will be to neglect it when most necessary. Some builders practice covering their work with sand, removing it when the walk is thoroughly hardened. Such covering furnishes quite a satisfactory protection, if the sand is of sufficient depth. The sand covering conserves the moisture in the walk and assists in holding moisture added during the hardening of the concrete.

Canvas, tar paper or boards will afford protection against sun and rain. The first two of these are apt to be disturbed by wind, unless carefully weighted down, while boards are too unhandy, and if not placed with extreme care or used in conjunction with canvas or tar paper, are apt to conduct the rain onto the walk in a stream, thus causing more damage than the rain would otherwise do. The same protection used against rain and sun, will be ample against light frost, but during cold weather additional and more perfect protection is necessary.

Protecting Against Frost. In the first place, sidewalks should not be constructed during cold weather, but if it cannot be avoided, extreme care will be necessary. Extreme care means extra expense, but this should not prevent proper protection. Work may be protected against frost by covering with sand, as above suggested, followed by a covering of manure, which should be covered with canvas, or tar paper, in such a way as to form a drainage toward the curb. This covering of canvas or paper will help to retain the heat, besides protecting the walk against discoloration which might result from the percolation of water through the manure cover.

Heated Materials. Another precaution in winter work which should not be neglected is the use of heated water and aggregate. As the rate of hardening is influenced by the consistency, it is advisable to use less water when the temperature approaches the freezing point. The use of warm materials will greatly accelerate the hardening of the concrete, thus developing more rapidly in the walk a condition which makes it capable of resisting frost action. Even though heated materials are used, the surface covering should not be neglected, for by failure to protect the surface, the heat in the walk is rapidly radiated and the surface is exposed to frost action.

GRADES

Steep Grades. The principles which have been laid down apply equally to sidewalks built on level and inclined grades.

FIGURE 22.

FIGURE 23.

The necessity of providing perfect joints in a walk is distinctly shown in Figures 22 and 23. These figures also show the advisability of projecting the joints from the old into the new work, or the necessity of providing an open joint between walks laid at different times. In both pictures it is evident that had the joint in the center of the walk opened, the cracks would not have occurred. It is distinctly shown that the cracks discontinued at points where real joints were provided.

Walks are sometimes laid with too steep a pitch for safety, and although there may be little objection to them in fair weather, such walks become impassable when iced over during the winter season. Wooden walks are then laid over the cement to provide a surer foothold, but this expedient should be unnecessary. Steps should be built if the grade exceeds 20 degrees, but lesser grades are improved by laying the run with sufficient slope to afford drainage and putting in risers at suitable intervals. A further improvement is to give a roughened finish to the run by means of a wooden trowel or grooving tool.

FIGURE 24.

Change of Grade. The comfort of pedestrians demands that the grade in a walk shall not change suddenly excepting where steps are advisable. It is not unusual to find a break in continuity of the grade such as is illustrated in Figure 24. Here the higher walk was built last and is connected to the lower by a sharp bevel. The passer-by, unprepared for this interruption, is sure to stumble. If this walk had been built right, the change in grade would have been extended over the entire length of a slab. There was yet another abrupt change of grade between the point where this picture was taken and the last crossing, although the street was level throughout this distance. It would be well for every city and town to establish by ordinance the grades of sidewalks so as to insure a uniform grade from one street to the next.

Clearance About Trees. When trees intercept the line of the walk, provision should be made for growth, else the trees will expand and crack the concrete, as illustrated in Figure 25. The amount of clearance around the trunk will depend some-

FIGURE 25.

what on the age of the tree, being greater for young trees, but should never be less than 6 inches at any point. Trees whose roots grow laterally, or near the surface of the ground, are more troublesome than those whose roots grow deeply. Root growth fractures slabs, and the destruction thus begun is completed by frost action.

VAULT WORK

Beam Construction. The specifications forming a part of this booklet deal only with walk on an earth foundation, but for the benefit of those who may also be interested in beam and reinforced work, Figures 26 and 27 havc been prepared. The special features in vaulted construction are covered in the following quotation:

† "WALKS LAID OVER VAULTS, AREAWAYS, ETC. BEAM WORK

"**Substructure.** The substructure shall consist of steel I-beams set not more than five (5′) feet apart from center to center, the outer end of said beams to rest at least eight (8″) inches on the curb wall, and to be firmly bedded in masonry to the top flange of same. Where practicable, the inner end of said beam shall penetrate the building wall not less than six (6″) inches.

* * * *

"The top of the completed iron substructure shall be a plane parallel four (4″) inches below the top of the finished walk.

"The following sized steel cross-beams shall be used in construction:

"For ten (10′) foot span, eight (8″) inch beams, weighing seventeen and three-quarters ($17\frac{3}{4}$) pounds per foot.

* * * *

"For twelve (12′) foot span, nine (9″) inch beams, weighing twenty-five (25) pounds per foot.

* * * *

"**Concreting.** Between the beams set in place as above specified, and securely fastened to the lower flange of same, shall be placed temporarily arched forms or centers, smooth on the upper surface, which shall be removed when the concrete has become thoroughly set. Said forms to be so set that the top or crown of same shall be two (2″) inches below the top of the steel cross beams."

Figure 26 gives details of this construction and of the required forms and has been prepared with the idea of making the specifications somewhat clearer.

It will be noted that the plate which supports the arch form is arranged to be used with different sized beams by having the holes on one side in the form of a slot instead of round. The same scheme can be carried further if desired and a single plate may be made to apply to a greater variation of size of beams by having all holes slotted.

The same class of concrete should be used in all forms of walk construction. Therefore, by taking that portion of the

†From Specifications for Portland Cement Concrete Sidewalks, Board of Local Improvements, Chicago.

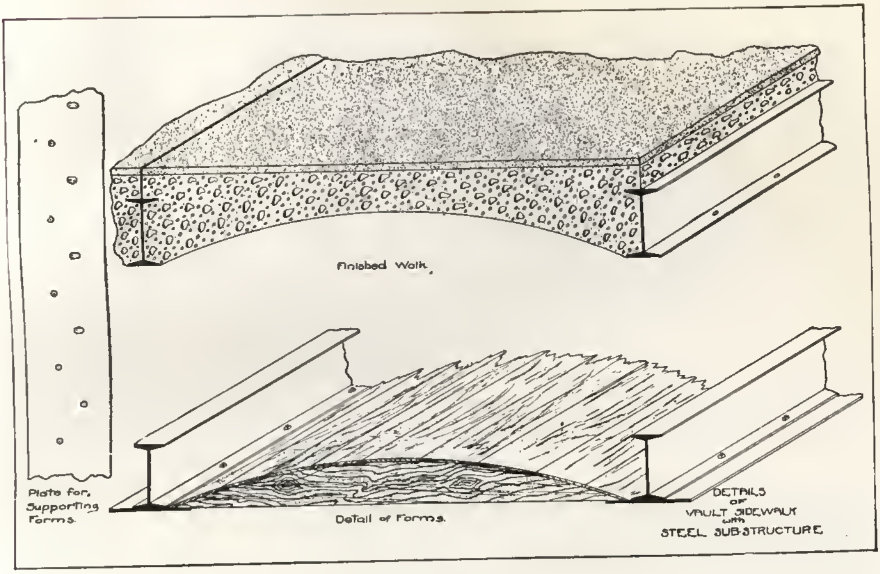


FIGURE 26.

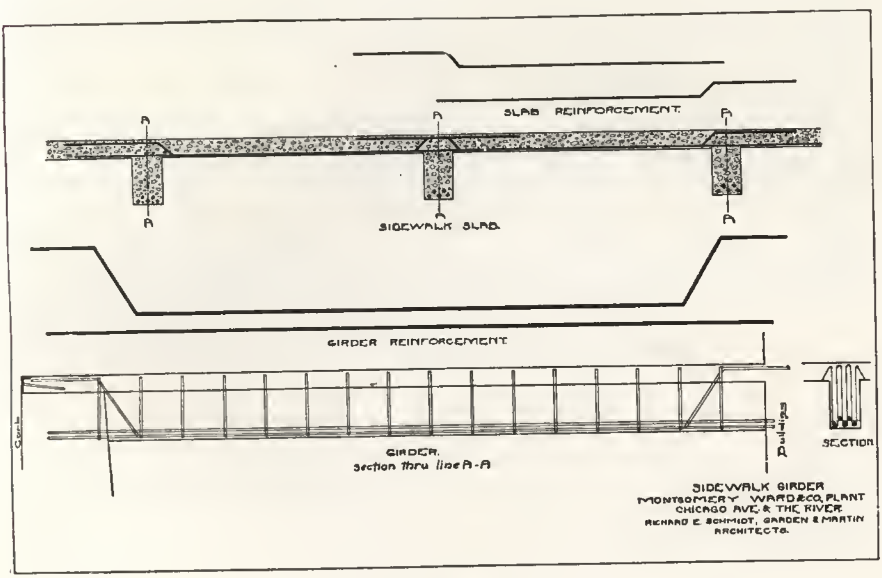


FIGURE 27.

specifications which deal with materials, mixing, etc., with the notes quoted from the Chicago specification, one will have a fairly comprehensive specification for vaulted work.

Reinforced Sidewalks. The use of reinforced concrete in sidewalk construction about office buildings, factories and warehouses is a development of the use of this material in buildings. The basements in such cases are extended so as to include all the available space under the walks. Reinforced concrete beams are cast in place simultaneously with the reinforced slabs on temporary wooden forms which cover the space between curb and building wall. Both ends of the beams must have a firm bearing, either on a solid wall or pier, and the reinforcement must extend well over the point of support to resist shear. The slabs should be reinforced in the direction of the run to take up the tensile stress. The fact that the slabs are flat makes this precau-

FIGURE 28.

A most miserable piece of sidewalk construction is shown in Figure 28. Apparently every rule and precaution necessary for the production of first-class work was disregarded in the placing of this walk. The fill was insufficiently and improperly prepared and was not protected. The base was weak, failing to support the top, which was not bonded to the base. This is an extreme example of shoddy construction.

tion necessary, but in "Beam Work," reinforcement is not needed because the arch carries the stresses. Reinforced slabs permit overhanging on the cantilever principle. The method of reinforcing

illustrated in Figure 27, is that used in the construction of the concrete warehouse of Montgomery Ward & Company, Chicago. In this particular case, the beams have a span of 20 feet and are placed 8 feet 9 inches on centers. They are 10½ inches wide and 23½ inches deep from top of the slabs. The sidewalk slabs arc made 6 inches thick and reinforced with ½ inch square bars on 30 inch centers.

COST OF WORK

The cost of cement walk will vary with the cost of materials and labor and with the experience of the men doing the work; also with the location of the walk, the amount of walk to be placed at one time and with its width. Some notes based on actual experience relative to the cost of a walk will doubtless prove of interest. The cost of materials given below includes delivery on the work.

Experience shows that a gang of six men can lay between 600 and 800 square feet of walk in a day of 10 hours and 700 square feet is considered as a day's work in arriving at these figures. This estimate is based on a 6-foot walk having a 4-inch base, consisting of 1 part cement, 2½ parts sand and 5 parts crushed stone, covered with a ¾-inch top of 1 part cement and 1½ parts sand. The stone ranged in size from ¼-inch to ¾-inch and contained 48 per cent. voids. A good grade of lake sand passing a ¼-inch screen was used. The sand contained 36 per cent. voids. The mixing was done by hand.

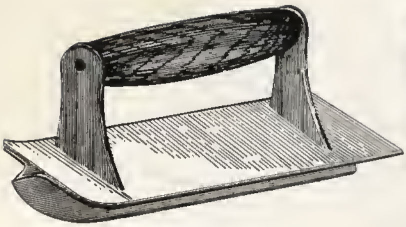
LABOR

One Finisher @ $5.00 per day	$ 5.00
Five Laborers @ $2.00 " "	10.00
Total cost of labor per 100 sq. ft...............	2.14

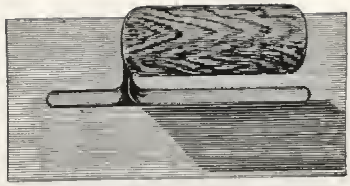
MATERIALS

Cement,	2.5 barrels,	@ $2.00	per barrel......	$ 5.00
Stone,	1.11 cu.yds.	@ $1.50	" cu. yd......	1.66
Sand,	.77 "	@ $1.00	" " ...	.77
Cinders,	2.7 "	@ .50	" " ...	1.35
Total cost of materials for 100 square feet........				8.78
Total cost of laying 100 square feet.............				10.92

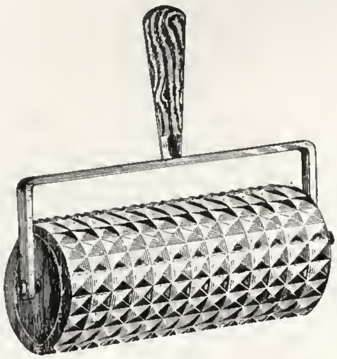
It should be noted that this estimate provides for a walk where an excavation for the sub-base was necessary, as shown in Figure 1.



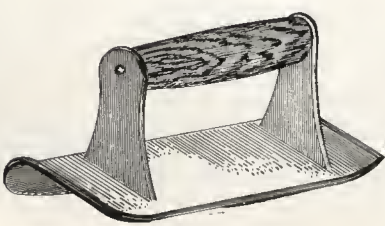
GROOVER



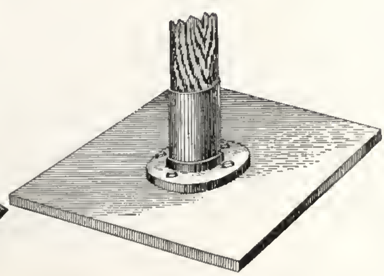
FINISHING TROWEL



ROLLER



EDGER



RAMMER

FIGURE 29.

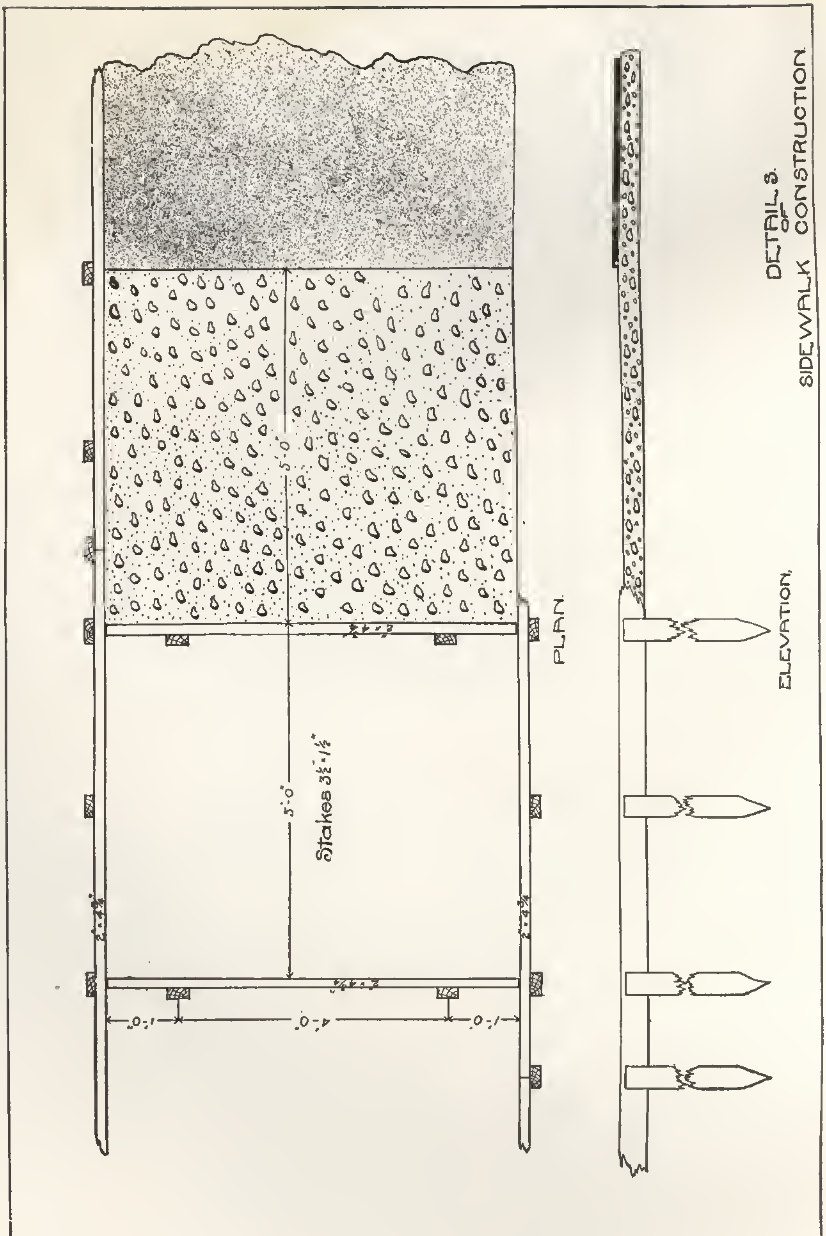
Metal tools used in cement sidewalk construction.

TOOLS AND EQUIPMENT

Successful sidewalk construction is much more dependent upon experience and sound judgment than upon the capital invested. Few special tools are necessary, and many of them can be made at home. See Figure 10, page 28. Several gauges will be required, corresponding to the different widths in which walks are laid. The gauges should be made of wood $\frac{7}{8}$-inch thick, and formed to determine the grade of the base and sub-base relative to the finished grade of the walk. The straight edge may be a piece of $\frac{7}{8}$-inch wood about 3 inches wide, or a light metal bar, and is used in working the top down to the grade established by the side forms. The wooden finishing trowel is made from a board 6 inches by 12 inches and provided with a hewn handle. The finish produced by this tool is preferable to that given by the steel trowel illustrated in Figure 29.

The wooden tamper shown in Figure 10 will answer very well for home jobs, but where any quantity of work is contemplated, a steel rammer should be provided. The square shape permits working in corners and closer to forms, and is preferable to a round tamper. Where the top is tamped from the base mortar, the special form of rammer illustrated in Figure 17 is also used. The groover has a steel blade $\frac{1}{2}$-inch deep and is used for marking slabs and running over joints from which parting strips have been removed. The edger is used to round off the edges of a walk with a radius of about $\frac{1}{2}$-inch. The set of metal tools illustrated in Figure 29 can be purchased from hardware dealers for about \$10.00. The tooth roller, which is not an essential tool, is the most expensive item, costing \$6.00. There are on the market various modifications of the tools illustrated, and also tools for special work. It is desirable to have a special die made with which to imprint the work with the contractor's name, address and year of construction.

In addition to the tools mentioned and the measuring box described on page 28, the equipment should contain a tool-box, saw, hammer, hatchet, spirit level, square, 6-foot rule, 50-foot tape, "chalk line," shovels, picks, trowels, steel wheelbarrows, mixing platform, screens, water buckets, sprinkling can, tarpaulin, lanterns and oil can, parting strips, stakes and lumber for side forms and for protecting the work. This outfit is sufficient for ordinary requirements.


DETAILS OF SIDEWALK CONSTRUCTION
PLAN
ELEVATION
Stakes 3½"×1½"
5'-0"
5'-0"
1'-0"
4'-0"
1'-0"
FIGURE 30.

SPECIFICATIONS FOR PORTLAND CEMENT SIDEWALKS

MATERIALS

Portland Cement. The cement shall conform in every detail to the Standard Specifications for Portland Cement adopted by the American Society for Testing Materials.

Sand. The sand shall pass a No. 4 screen and be free from all foreign matter, excepting loam or clay, which will be permitted if the quantity does not exceed 5 per cent. and when these ingredients do not occur as a coating on the sand grains.

Not more than 40 per cent. shall be retained on a No. 10 mesh,
Or 35 per cent. pass a No. 10 and be retained on a No. 20,
Or 35 per cent. pass a No. 20 and be retained on a No. 30,
Or 35 per cent. pass a No. 30 and be retained on a No. 40,
Or 35 per cent. pass a No. 40 and be retained on a No. 50.
Not more than 20 per cent. shall pass a No. 50 mesh,
Or 70 per cent. pass a No. 10 and be retained on a No. 40,
Or 70 per cent. pass a No. 20 and be retained on a No. 50.

Stone. Stone shall be crushed from clean, sound, hard, durable rocks; shall be screened dry through a 1¼-inch mesh and be retained on a ¼-inch mesh.

Screenings. Screenings through a ¼-inch mesh from the crushed stone specified above, may be substituted for sand if approved by the engineer. They shall be clean, dry, well graded and free from excessive dust, which shall not occur as a coating on the particles of stone.

Gravel. Gravel shall be clean, hard and vary in sizes from that retained on a ¼-inch mesh to the largest passed by a 1¼-inch mesh.

Unscreened Gravel. Unscreened gravel shall be clean, hard and contain no particles larger than 1¼-inch. The proportion of fine and coarse particles must be determined and corrected to agree with the requirements for concrete. (See Base, Proportioning.)

Foundation. Clean, hard cinders, slag, gravel, crushed stone or broken brick shall be used for the sub-base. The material shall not be smaller than ½-inch nor exceed 4 inches in the largest dimension.

Water. Water shall be reasonably clean, free from oil, acid and alkalis.

Tile. Tile shall be cement or hard burned clay tile of uniform size and shape and free from cracks.

SUB-GRADE

Depth Below Grade of Walk; Slope. The sub-grade shall be not less than $12\frac{3}{4}$ inches below the finished surface of the walk and shall have a slope toward the curb of not less than $\frac{1}{2}$-inch per foot.

Depth of Layers. All soft or spongy places shall be dug out, and all depressions filled with suitable filling material, which shall be thoroughly compacted by flooding and tamping in layers not exceeding 6 inches in thickness.

Deep Fills. When, to bring the walk to grade, a fill exceeding 1 foot in thickness is required, it shall be made in a manner satisfactory to the engineer. The top of all fills shall extend beyond the walk on each side at least 2 feet, and the sides shall have a slope of not less than $1:1\frac{1}{2}$.

Drainage. When required, a suitable drainage system shall be installed and connected with sewers or other drains indicated by the engineer. See Note 1.

SUB-BASE

A sub-base shall be provided whenever required by the engineer.

Width; Thickness. The sub-base shall consist of cinders or other suitable materials hereinbefore specified. The material shall be evenly spread upon the sub-grade, shall extend at least two inches beyond the edges of the walk and shall be thoroughly rammed to a surface $4\frac{3}{4}$ inches below the final grade of the walk.

Wet Material. While compacting the sub-base the material shall be kept thoroughly wet and shall be in that condition when the concrete is deposited.

FORMS

Materials. When wooden forms are used they shall be free from warp, and not less than 2 inches thick. All mortar and dirt shall be removed from forms that have been used.

Setting. The forms shall be well staked to the lines and grades given by the engineer, and their upper edges shall conform with finished grade of the walk, which shall have sufficient rise from

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Note 1. A trench 12 inches by 12 inches, immediately below the outer edge of the sub-base, in which is laid a 4-inch tile surrounded by material similar to that used in the foundation, provides a satisfactory drain.

the curb to provide proper drainage, but this rise shall not exceed $\frac{1}{4}$-inch per foot, except where such rise shall parallel the length of the walk.

Cross Forms. At each slab division, cross-forms shall be put in the full width of the walk and at right-angles to the side forms.

Size of Slabs. Forms shall be so spaced that no slab shall contain more than 36 square feet or have any dimension greater than 6 feet.

Expansion Joint. A metal parting strip $\frac{1}{2}$-inch thick shall take the place of the cross-forms at least once in every 50 linear feet of walk. When the walk has become sufficiently hard, this parting strip shall be removed and the joint filled with suitable material prior to opening the walk to traffic. Similar joints shall be provided where new walk abuts curbing or other cement or stone walk.

Forms, Wet. All forms shall be thoroughly wetted before any material is deposited against them.

BASE

Proportioning. The concrete for the base shall be so proportioned that the cement shall overfill the voids in the sand by at least 5 per cent. and the mortar shall overfill the voids in the stone or gravel by at least 10 per cent. See Note 2.

When the voids are not determined, the concrete shall have the proportion of 1 part cement, 3 parts sand or screenings, and 5 parts stone or gravel. See Note 3.

Mixing. The sand shall be evenly spread on a level water-tight platform and the cement spread upon the sand. After thor-

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Note 2. To determine voids in sand, fill a vessel with sand and let net weight of sand equal B. Fill same vessel with water and let net weight of water equal A.

$$\text{Formula: Per cent. voids} = \frac{(A \times 2.65) - B}{A \times 2.65} 100$$

This formula may also be used in determining voids in crushed stone and screenings, by substituting for 2.65 the specific gravity of the stone.

The following is a more simple method for determining voids in coarse aggregate:

Fill a vessel level full with water and let net weight of the water equal C.

Remove the water, dry the vessel and fill it with the aggregate and let net weight of the aggregate equal B.

Add water slowly until it just appears on the surface and weigh. Let net weight of the aggregate and water equal A.

$$\text{Formula: Per cent. voids} = \frac{A - B}{C} 100$$

The larger the vessel, the more accurate the result.

Do not use a vessel of less than $\frac{1}{2}$ cubic foot capacity.

Note 3. A sack of cement weighing 94 pounds shall be considered to have a volume of 1 cubic foot.

oughly mixing the dry materials to a uniform color, they shall be formed into a crater or trench and practically all of the water required shall be added at one time and the mass turned until a homogeneous mortar of even consistency is obtained. Additional water required shall be added in the form of a spray. To this mortar shall be added the required amount of stone or gravel previously drenched and the whole shall then be mixed until all the aggregate is thoroughly coated with mortar.

Where unscreened gravel is used, the cement and gravel shall be thoroughly mixed dry until no streaks of cement are visible. Water shall be added as previously described in sufficient quantity to render, when thoroughly mixed, a concrete equivalent to that specified above.

Water may be added during the process of mixing, but the concrete shall be turned at least once immediately after its addition.

Machine Mixing. Machine mixing will be acceptable when a concrete equivalent in quality to that specified above is obtained. The mixing of mortar and concrete shall be thorough and satisfactory to the engineer.

Retempering. Retempering will not be permitted.

Thickness. The base shall be at least 4 inches thick, and the top surface at least $\frac{3}{4}$ of an inch below the finished surface of the walk.

Depositing. The concrete shall be deposited before it shows any tendency to harden, but in all cases shall be deposited within 40 minutes after being mixed and shall be transferred to the forms in water-tight wheelbarrows. The wheelbarrows shall not be filled so full as to permit mortar to slop out and shall not be run over the freshly laid concrete.

The concrete shall be spread evenly and tamped until water flushes to the top. After the concrete has been thoroughly rammed against the cross-forms, they shall be removed and the material for the next slab deposited so as to preserve the joint. Care shall be taken to maintain rectangular slabs of uniform size.

Care of Base. Workmen shall not be permitted to walk on freshly laid concrete and where sand or dust gets on the base it shall be carefully removed before the wearing course is applied.

WEARING COURSE

Mixing. The mortar shall be mixed in the same manner as the mortar for the base, but in the proportion of 1 cement to 1½ sand or screenings, and it shall be of such consistency that it will not require tamping, but will be readily floated with a straight edge.

Thickness. The wearing course shall have a thickness of at least ¾ of an inch.

Depositing. The mortar shall be spread on the base within 30 minutes after mixing, or before it shows any tendency to harden, but in no case shall more than 50 minutes elapse between the time that the concrete for the base is mixed, and the time that the wearing course is placed.

Slab Markings. After working the top to an approximately true surface, the slab markings shall be made directly over the joints in the base with a tool which shall cut clear through to the base and completely separate the wearing courses of adjacent slabs; this tool to be followed by a tool forming a groove at least ½-inch deep.

Edges Rounded. The slabs shall be rounded on all surface edges to a radius of about ½ of an inch.

Troweling. When partially set, the surface shall be troweled smooth.

Roughened Surfaces. On grades exceeding 5 per cent. the surface shall be roughened.

When a roughened surface is required, it may be obtained by the use of a grooving tool, toothed roller, brush, wooden trowel or other suitable tool; or by working coarse sand or screenings into the surface.

Color. If artificial coloring is desired, only mineral colors shall be used which shall be incorporated with the entire wearing surface.

PROTECTION

When completed, the walk shall be kept moist and protected from traffic and the elements for at least three days. The forms shall not be removed during this time and upon removal earth shall be banked against the edge of the walk.

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